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ABSTRACT

Based on a summary of research findings on best teacher practices in mathematics education, which is presented in part 1, the companion to this digest, recommendations are given to improve mathematics teaching practices. Among the recommendations are: students can learn both concepts and skills by solving problems; whole-class discussion following individual and group work improves student achievement; and using calculators in the learning of mathematics can result in increased achievement and improved student attitudes. (MM)

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Digest

Improving Student Achievement in Mathematics

Part 2: Recommendations for the Classroom

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SE 064 318 | ERIC Clearinghouse for Science, Mathematics, and Environmental Education | EDO-SE-00-10

The number of research studies conducted in mathematics education over the past three decades has increased dramatically (Kilpatrick, 1992). The results from these studies, together with relevant findings from research in other domains, such as cognitive psychology, are used to identify the successful teaching strategies and practices.

Teaching and learning mathematics are complex tasks. The effect on student learning of changing a single teaching practice may be difficult to discern because of the simultaneous effects of both the other teaching activities that surround it and the context in which the teaching takes place. Research findings indicate that certain teaching strategies and methods are worth careful consideration as teachers strive to improve their mathematics teaching practices. To readers who examine the suggestions that follow, it will become clear that many of the practices are interrelated. There is also considerable variety in the practices that have been found to be effective, and so most teachers should be able to identify ideas they would like to try in their classrooms. The practices are not mutually exclusive; indeed, they tend to be complementary. The logical consistency and variety in the suggestions from research make them both interesting and practical.

For a summary of the research findings on which these recommendations are based, please see the companion to this Digest, *Improving Student Achievement in Mathematics, Part 1: Research Findings* (EDO-SE-00-09)

1. **The extent of the students' opportunity to learn mathematics content bears directly and decisively on student mathematics achievement.**

It seems prudent to allocate sufficient time for mathematics instruction at every grade level. Short class periods in mathematics, instituted for whatever practical or philosophical reason, should be seriously questioned. Of special concern are the 30-35 minute class periods for mathematics being implemented in some middle schools.

Textbooks that devote major attention to review and that address little new content each year should be avoided, or their use should be heavily supplemented. Teachers should use textbooks as just one instructional tool among many, rather than feel duty-bound to go through the textbook on a one-section-per-day basis.

It is important to note that opportunity to learn is related to equity issues. Some educational practices differentially affect particular groups of students' opportunity to learn. For example, a recent American Association of University of Women study (1998) showed that boys' and girls' use of technology is markedly different. Girls take fewer computer science and computer design courses than do boys. Furthermore, boys often use computers to program and solve problems, whereas girls tend to use the computer primarily as a word processor. As technology is used in the mathematics classroom, teachers must assign tasks and responsibilities to students in such a way that both boys and girls have active learning experiences with the technological tools employed.

2. **Focusing instruction on the meaningful development of important mathematical ideas increases the level of student learning.**

- Emphasize the mathematical meanings of ideas, including how the idea, concept or skill is connected in multiple ways to other mathematical ideas in a logically consistent and sensible manner.
- Create a classroom learning context in which students can construct meaning.
- Make explicit the connections between mathematics and other subjects.
- Attend to student meanings and student understandings.

3. **Students can learn both concepts and skills by solving problems.**

There is evidence that students can learn new skills and concepts while they are working out solutions to problems. Development of more sophisticated mathematical skills can also be approached by treating their development as a problem for students to solve. Research suggests that it is not necessary for teachers to focus first on skill development and then move on to problem solving. Both can be done together. Skills can be developed on an as-needed basis, or their development can be supplemented through the use of technology. In fact, there is evidence that if students are initially drilled too much on isolated skills, they have a harder time making sense of them later.

4. **Giving students both an opportunity to discover and invent new knowledge and an opportunity to practice what they have learned improves student achievement.**

Balance is needed between the time students spend practicing routine procedures and the time they devote to inventing and discovering new ideas. Teachers need not choose between these; indeed, they must not make a choice if students are to develop the mathematical power they need.

To increase opportunities for invention, teachers should frequently use non-routine problems, periodically introduce a lesson involving a new skill by posing it as a problem to be solved, and regularly allow students to build new knowledge based on their intuitive knowledge and informal procedures.

5. **Teaching that incorporates students' intuitive solution methods can increase student learning, especially when combined with opportunities for student interaction and discussion.**

Research results suggest that teachers should concentrate on providing opportunities for students to interact

SE064318

in problem-rich situations. Besides providing appropriate problem-rich situations, teachers must encourage students to find their own solution methods and give them opportunities to share and compare their solution methods and answers. One way to organize such instruction is to have students work in small groups initially and then share ideas and solutions in a whole-class discussion.

6. Using small groups of students to work on activities, problems and assignments can increase student mathematics achievement.

When using small groups for mathematics instruction, teachers should:

- Choose tasks that deal with important mathematical concepts and ideas.
- Select tasks that are appropriate for group work.
- Consider having students initially work individually on a task and then follow with group work where students share and build on their individual ideas and work.
- Give clear instructions to the groups and set clear expectations for each (for each task or each group?).
- Emphasize both group goals and individual accountability.
- Choose tasks that students find interesting.
- Ensure that there is closure to the group work, where key ideas and methods are brought to the surface either by the teacher or the students, or both.

7. Whole-class discussion following individual and group work improves student achievement.

It is important that whole-class discussion follows student work on problem-solving activities. The discussion should be a summary of individual work in which key ideas are brought to the surface. This can be accomplished through students presenting and discussing their individual solution methods, or through other methods of achieving closure that are led by the teacher, the students, or both.

Whole-class discussion can also be an effective diagnosis tool for determining the depth of student understanding and identifying misconceptions. Teachers can identify areas of difficulty for particular students, as well as ascertain areas of student success or progress.

8. Teaching mathematics with a focus on number sense encourages students to become problem solvers in a wide variety of situations and to view mathematics as a discipline in which thinking is important.

Competence in the many aspects of number sense is an important mathematical outcome for students. Over 90% of the computation done outside the classroom is done without pencil and paper, using mental computation, estimation or a calculator. However, in many classrooms, efforts to instill number sense are given insufficient attention.

As teachers develop strategies to teach number sense, they should strongly consider moving beyond a unit-skills approach (i.e. a focus on single skills in isolation) to a more integrated approach that encourages the development of number sense in all classroom activities, from the development of computational procedures to mathematical problem-solving.

9. Long-term use of concrete materials is positively related to increases in student mathematics achievement and improved attitudes towards mathematics.

Research suggests that teachers use manipulative materials regularly in order to give students hands-on experience that helps them construct useful meanings for the mathematical ideas they are learning. Use of the same materials to teach multiple ideas over the course of schooling shortens the amount of time it takes to introduce the material and helps students see connections between ideas.

The use of concrete material should not be limited to demonstrations. It is essential that children use materials in meaningful ways rather than in a rigid and prescribed way that focuses on remembering rather than on thinking.

10. Using calculators in the learning of mathematics can result in increased achievement and improved student attitudes.

One valuable use for calculators is as a tool for exploration and discovery in problem-solving situations and when introducing new mathematical content. By reducing computation time and providing immediate feedback, calculators help students focus on understanding their work and justifying their methods and results. The graphing calculator is particularly useful in helping to illustrate and develop graphical concepts and in making connections between algebraic and geometric ideas.

In order to accurately reflect their meaningful mathematics performance, students should be allowed to use their calculators in achievement tests. Not to do so is a major disruption in many students' usual way of doing mathematics, and an unrealistic restriction because when they are away from the school setting, they will certainly use a calculator in their daily lives and in the workplace.

References

American Association of University Women. ((1998). *Gender gaps where schools still fail our children.* Washington, DC: Author.

Kilpatrick, J. (1992). A history of research in mathematics education. In Grouws, D. A., (Ed.), *Handbook of research on mathematics teaching and learning.* (pp. 3-38) NY: Macmillan.

Other sources of information about best practices

NCTM Illuminations
http://illuminations.nctm.org/index2.html

National Center for Improving Student Learning and Achievement in Mathematics and Science
http://www.wcer.wisc.edu/ncisla/

Eisenhower National Clearinghouse for Mathematics and Science Education, http://enc.org

An expanded version of the ideas presented in this Digest is available online at http://www.ibe.unesco.org/Publications/Practice/prac04e.pdf

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